

## Title of the Invention:

PERMANENT MAGNET ELECTRIC ROTATING MACHINE AND  
ELECTROMOTIVE VEHICLE USING PERMANENT MAGNET ELECTRIC  
ROTATING MACHINE

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## Background of the Invention:

## (Technical Field)

The present invention relates to a permanent magnet electric rotating machine and an electromotive vehicle using a permanent magnet electric rotating machine and in particular to a permanent magnet electric rotating machine in which permanent magnets are used as a magnetic flux generating means and an electromotive vehicle such as an electric vehicle using a permanent magnet electric rotating machine.

## 10 15 (Prior Arts)

Up to now as one kind of a electric rotating machine, a permanent magnet electric rotating machine has used, in which permanent magnets of the permanent magnet electric rotating machine are used as a magnetic field generating means for a rotor.

20 25 As a conventional permanent magnet electric rotating machine, there is a surface magnet structure permanent magnet electric rotating machine, namely plural permanent magnets of the permanent magnet electric rotating machine are arranged in parallel and fixed on a surface of a rotor and further adjacent

permanent magnets are arranged to have a reversal polarity at a peripheral direction.

However, in the above stated surface magnet structure permanent magnet electric rotating machine, 5 during a high speed rotation there is a possibility in which the permanent magnet may peel off according to a centrifugal force.

A permanent magnet rotor having a permanent magnet embedding structure permanent magnet electric rotating machine is disclosed in Japanese patent laid-open publication No. Hei 5-76,146. Namely, in the above 10 stated permanent magnet rotor permanent magnets are inserted and fixed to holes, such holes extend into an interior portion of the rotor toward an axial direction.

Further, so as to aim a simplification of a 15 structure of a case in which the rotor having the permanent magnet embedding structure of the permanent magnet electric rotating machine is performed to carry out a skew structure, such a permanent magnet structure 20 of the permanent magnet electric rotating machine is disclosed in Japanese patent laid-open publication No. Hei 5-236,687. Namely, in this permanent magnet structure permanent magnet electric rotating machine, a 25 space is formed from an end face of each of the permanent magnets which are installed in an interior portion of a rotor to an outer periphery of the rotor.

However, in the above stated prior arts, there is a problem in which an obtaining of a reluctant torque by auxiliary magnetic poles and a reduction in a cogging torque or a torque pulsation are not incompatible. Hereinafter, in this specification, the torque pulsation indicates one putting both of the reluctant torque and the cogging torque.

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In the permanent magnet embedding structure permanent magnet electric rotating machine, utilizing the rotor member provided between the adjacent permanent magnets as the auxiliary magnetic pole, a composite vector of an armature magnetomotive force of a stator is controlled to direct toward a side of a rotation direction but not to direct toward a central 10 position direction of the auxiliary magnetic pole, as a result, the reluctant torque can be obtained.

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This reluctant torque is added to a main torque generated by the permanent magnets and a whole torque of the permanent magnet electric rotating machine can be increased. Therefore, an efficiency in the 15 permanent magnet embedding structure permanent magnet electric rotating machine can be heightened.

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On the other hand, in the conventional permanent magnet electric rotating machine, since the permanent magnets for generating always a magnet flux regardless of an existence of an electric power supply are used, the rotor can receive always a force which is one 25

corresponding to a positional relationship between the permanent magnet and a stator salient pole portion and during the rotation time the above stated force changes pulsatively. This pulsating force appears as the torque pulsation.

5 This torque pulsation obstructs a smooth rotation of the rotor and this causes a problem in which a stable operation as the permanent magnet electric rotating machine can not be obtained.

10 In the permanent magnet rotor of the permanent magnet electric rotating machine shown in Japanese patent laid-open publication No. Hei 5-76,146, since the rotor has the auxiliary magnetic poles, it is possible to obtain the reluctance torque. However, 15 since a distance formed between the permanent magnet and the auxiliary magnetic pole is minute toward the periphery direction, an abrupt change in a magnet flux density distribution appears in the minute distance portion, accordingly the torque pulsation causes.

20 On the other hand, in the permanent magnet electric rotating machine shown in Japanese patent laid-open publication No. Hei 5-236,687, the space is formed between the adjacent permanent magnets and further in this space an adherence property fill-up 25 member comprised of a non-magnetic body is filled up.

Accordingly, a magnet flux density distribution between the adjacent permanent magnets becomes

moderately, it hardly generate the cogging torque or the torque pulsation. However, the above stated space or the fill-up member does not work a role as the auxiliary magnetic pole, therefore the reluctant torque 5 can not be obtained.

**Summary of the Invention:**

An object of the present invention is to provide a permanent magnet electric rotating machine and an 10 electromotive vehicle using a permanent magnet electric rotating machine wherein a torque pulsation can be restrained by obtaining a reluctant torque according to auxiliary magnetic poles.

According to the present invention, a permanent 15 magnet electric rotating machine comprises a stator performed a winding to a stator iron core, plural permanent magnet insertion holes for forming magnetic pole piece portions at a side of the stator through auxiliary magnetic pole portions, and a rotor embedding plural permanent magnets in the permanent magnet 20 insertion hole, the rotor arranged to the stator with a rotation air gap.

A magnetic gap is provided between at least one 25 the permanent magnet and at least one the auxiliary magnetic pole portion which is adjacent to at least one the permanent magnet to a peripheral direction.

The magnetic gap makes moderately the change in the magnetic flux density distribution at the peripheral direction between the permanent magnet and the auxiliary magnetic pole portion, accordingly the 5 torque pulsation can be decreased.

Therefore, the magnetic gap can be formed according to merely the space or according to the arrangement or the filling-up of the non-magnetic material.

10 Further, this magnetic gap can be formed at both ends of the permanent magnets and this magnetic gap can be formed at one end of the peripheral direction of the permanent magnet complying with a request of the rotation direction of the permanent magnet electric 15 rotating machine and a use for applying the permanent magnet electric rotating machine.

However, the provision of the above stated magnetic gap at the peripheral direction end portion of the permanent magnet, there is a possibility that the 20 positioning of the permanent magnet becomes unstable during the high speed rotation, etc..

For the above stated reasons, according to the present invention, a dent portion is provided at a bottom portion of the permanent magnet, and on the dent portion the permanent magnet is arranged and installed 25 stable. According to present invention, a non-magnetic material member is arranged in the magnetic

gap.

Further, since the magnetic gap can be enough to make moderately the magnetic flux density distribution against the stator, by varying the dimension or the width (space) of the magnetic gap, it is possible to assist the functions of the auxiliary magnetic pole portion.

According to the present invention, a peripheral direction width of the magnetic gap at a face of the stator side (an outer peripheral portion of the stator) is formed larger than a peripheral direction width of the magnetic gap at a face of an anti-stator side (an inner peripheral portion of the stator).

According to the present invention, a peripheral direction cross-section of the magnetic gap is a triangular shape. Therefore, it is possible to circulate the magnetic flux of the auxiliary magnetic pole portions around the permanent magnets, as a result the large reluctance torque of the permanent magnet electric rotating machine can be obtained.

According to the present invention, the magnetic pole piece portion is connected to the auxiliary magnetic pole portion through a bridge portion, and a stator side surface and a magnetic gap side surface of the bridge portion are formed substantially in parallel. The bridge portion is formed to extend toward vertically to an inclined face of the magnetic gap.

Therefore, it is possible to restrain the magnetic flux for leaking from the permanent magnets and the member of the stator side of the magnetic gap to the auxiliary magnetic pole portions.

5       Further, according to the present invention, the bridge portion is formed to extend toward vertically to an inclined face of the magnetic gap, accordingly the centrifugal force given on the permanent magnet can be supported according to the tensile force of the bridge portion, as a result the permanent magnet electric 10 rotating machine capable of the higher speed rotation can be obtained.

15       According to the present invention, a permanent magnet electric rotating machine comprises a stator performed a winding to a stator iron core, plural permanent magnet insertion holes for forming magnetic pole piece portions at a side of the stator through auxiliary magnetic pole portions, and a rotor embedded plural permanent magnets in the permanent magnet 20 insertion holes, the rotor arranged to the stator with a rotation air gap. A magnetic gap is provided between at least one the magnetic piece portion and at least one the auxiliary magnetic pole portion.

25       The above stated magnetic gap can make moderately the magnetic flux density distribution at the peripheral direction of the rotor between the permanent magnet and the auxiliary magnetic pole portion.

According to the present invention, the magnetic gap contacts to a peripheral direction end portion of a face of a stator side of the permanent magnet. The magnetic gap extends toward an inner side of the permanent magnet.

According to the present invention, the magnetic gap extends with a rectangular shape toward an inner side of the permanent magnet. Therefore, it is possible to restrain the magnetic flux for leaking from the face of the stator side of the permanent magnet to the auxiliary magnetic pole portion.

According to the present invention, a permanent magnet electric rotating machine comprises a stator performed a winding to a stator iron core, plural permanent magnet insertion holes for forming magnetic pole piece portions at a side of the stator side through auxiliary magnetic pole portions, and a rotor embedded plural permanent magnets in the permanent magnet insertion holes, the rotor arranged to the stator with a rotation air gap.

A magnetic gap is provided between at least one the magnetic piece portion and at least one the auxiliary magnetic pole portion, and the magnetic pole piece portion is fixed to the auxiliary magnetic pole portion through a non-magnetic magnetic pole piece supporting member.

According to the present invention, the magnetic pole piece supporting member has J shape and the magnetic pole piece supporting member is inserted from both axis of the rotor iron core. Therefore, the 5 centrifugal force of the permanent magnet given on the magnetic pole piece portion can be supported according to the auxiliary magnetic pole portion.

According to the present invention, a permanent magnet electric rotating machine comprises a stator 10 performed a winding to a stator iron core, plural permanent magnet insertion holes for forming magnetic pole piece portions at a side of the stator through auxiliary magnetic pole portions, and a rotor embedded plural permanent magnets in the permanent magnet 15 insertion holes, the rotor arranged to the stator with a rotation air gap.

A magnetic gap is provided between at least one the magnetic piece portion and at least one the auxiliary magnetic pole portion, a permanent magnet 20 supporting member is arranged between the magnetic pole piece portion and the permanent magnet and the permanent magnet supporting member is assembled according to a magnetic material member and a non-magnetic material member.

25 The magnetic material of the permanent magnet supporting member is arranged between the magnetic pole piece portion and the permanent magnet, and the non-

magnetic material member of the permanent magnet supporting member is engaged with the magnetic pole piece portion. Therefore, the supporting force against the centrifugal force given on the permanent magnet can be increased.

According to the present invention, a non-magnetic material member is arranged in the magnetic gap. Therefore, the supporting force against the centrifugal force given on the permanent magnet can be increased.

10 According to the present invention, a peripheral direction width of the permanent magnet is smaller than a peripheral direction width of the auxiliary magnetic pole portion. Therefore, the centrifugal force given on the permanent magnet can be lessened effectively.

15 According to the present invention, an electromotive vehicle is driven by a permanent magnet electric rotating machine. Therefore, the electromotive vehicle having the small cogging torque and the stable drive apparatus can be provided.

20 The permanent magnet electric rotating machine according to the present invention can be applied to a generator and an electric motor, an inner rotor type and an outer rotor type permanent magnet electric rotating machine, a rotary type and a linear type 25 permanent magnet electric rotating machine, a concentric winding stator structure and a salient winding stator structure permanent magnet electric

rotating machine.

The present invention does not depend on the shape of the permanent magnet, therefore the permanent magnet having a rectangular body, an arc shape, and a 5 trapezoid shape. etc. can be applied and the similar effects can be obtained.

**Brief Description of Drawings:**

10 Fig. 1 is a periphery direction cross-sectional view showing one embodiment of a permanent magnet electric rotating machine according to the present invention;

15 Fig. 2 is an enlarged view showing a surrounding portion of an optional permanent magnet of a rotor of the permanent magnet electric rotating machine shown in Fig. 1;

20 Fig. 3 is an axial direction cross-sectional view showing one embodiment of the permanent magnet electric rotating machine shown in Fig. 1;

Fig. 4A is a functional explanation view showing a 25 rotor member of the permanent magnet electric rotating machine shown according to the present invention in Fig. 2;

Fig. 4B is a graph showing a magnetic flux density distribution of a rotor member of the permanent magnet electric rotating machine according to the present invention shown in Fig. 2;

Fig. 5A is a functional explanation view showing a rotor member of a permanent magnet electric rotating machine according to a prior art;

5 Fig. 5B is a graph showing a magnetic flux density distribution of a rotor member of a permanent magnet electric rotating machine according to a prior art;

10 Fig. 6 is a peripheral direction cross-sectional view showing another embodiment of a permanent magnet electric rotating machine according to the present invention;

Fig. 7 is a peripheral direction cross-sectional view showing a rotor of another embodiment of the permanent magnet electric rotating machine according to the present invention;

15 Fig. 8 is a peripheral direction cross-sectional view showing a rotor of a further embodiment of a permanent magnet electric rotating machine according to the present invention;

20 Fig. 9 is a peripheral direction cross-sectional development view showing a rotor of a furthermore embodiment of a permanent magnet electric rotating machine according to the present invention;

25 Fig. 10 is a peripheral direction cross-sectional development view showing a rotor of a furthermore embodiment of a permanent magnet electric rotating machine according to the present invention;

Fig. 11 is a peripheral direction cross-sectional development view showing a rotor of a furthermore embodiment of a permanent magnet electric rotating machine according to the present invention;

5 Fig. 12 is a peripheral direction cross-sectional view showing a rotor of a furthermore embodiment of a permanent magnet electric rotating machine according to the present invention;

10 Fig. 13 is a squint view showing a magnetic pole supporting member shown in Fig. 12;

Fig. 14 is an axial direction cross-sectional view showing the permanent magnet electric rotating machine shown in Fig. 12;

15 Fig. 15 is a peripheral direction cross-sectional view showing a rotor of a furthermore embodiment of a permanent magnet electric rotating machine according to the present invention; and

20 Fig. 16 is a peripheral direction cross-sectional view showing a rotor of a furthermore embodiment of a permanent magnet electric rotating machine according to the present invention.

**Description of the Invention:**

25 Hereinafter, one embodiment of a permanent magnet electric rotating machine according to the present invention and an electromotive vehicle using a permanent magnet electric rotating machine according to

the present invention will be explained in detail referring to figures.

5 Fig. 1 is a peripheral direction cross-sectional view showing one embodiment of an inner rotor type concentrated winding stator structure permanent magnet electric rotating machine according to the present invention.

10 A permanent magnet electric rotating machine is constituted by a stator 1 and a rotor 2, and the stator 1 and the rotor 2 are arranged with a rotation air gap each other as shown in figure.

15 The stator 1 comprises a stator iron core 3 and a stator winding 4. The stator iron core 3 comprises a core portion 5 and a stator salient pole portion 6. In the core portion 5, a magnetic circuit is formed so to pass a magnetic flux to the stator salient pole portion 6. In this stator salient pole portion 6, the stator winding 4 is wound round concentrately.

20 The rotor 2 comprises a shaft 7, a rotor iron core 8 and plural permanent magnets 9. In the rotor iron core 8, plural permanent magnet insertion holes 10 for inserting the permanent magnets 9 and holes for passing through the shaft 7 are punched out at an axial direction. The permanent magnets 9 are inserted in and fixed respectively to the permanent magnet insertion 25 holes 10. The shaft 7 is inserted in and fixed to the shaft passing-through holes.

As stated in above, this embodiment of the permanent magnet electric rotating machine according to the present invention is a permanent magnet embedding structure electric rotating machine. By arranging the 5 permanent magnets 9 to the rotor 2 in a ring form, a member formed between the adjacent permanent magnet insertion holes 10 can be functioned as an auxiliary magnetic pole 16. Namely, the permanent magnets 9 are arranged separately and equally on a same circumference 10 with same distance in the respective permanent magnet insertion hole 10 of the rotor 2.

In other words, using a control apparatus (not shown in figure), it can control a composite force of an armature electromotive force according to the stator 15 winding 4 to direct toward a side of a rotation direction but not direct toward a side of a central position direction of the auxiliary magnetic pole 16.

Accordingly, a magnetic flux generated from the stator winding 4 circulates the permanent magnets 9 20 through the auxiliary magnetic poles 16 and then a reluctance torque generates. This is effective in particular during a low speed operation condition of the permanent magnet electric rotating machine. And further since the above stated reluctance torque is 25 added to an ordinary torque according to the permanent magnets 9, a high torque as an electric motor, for example, can be obtained.

Fig. 3 is a cross-sectional structure at an axial direction showing one embodiment of a permanent magnet electric rotating machine according to the present invention.

5 The stator 1 is fixed to an inner periphery face of a housing 11 and the shaft 7 which is inserted in and fixed to the rotor 2 can rotate freely with a rotation air gap against the stator 1 and further the shaft 7 is contacted and held by bearing members 13 and end bracket members 12.

10 In the above stated embodiment of the permanent magnet electric rotating machine according to the present invention, as to a material for the rotor iron core 8 it employs the rotor iron core 8 having a higher magnetic permeability than a magnetic permeability of the permanent magnet 9, for example it employs the stator iron core 3 having a high magnetic permeability such as a silicon steel plate.

15 Since the rotor iron core 8 having the above higher magnetic permeability of the permanent magnet electric rotating machine is employed, it is possible to lessen an eddy current loss which generates in an interior portion of the permanent magnet 9 and further it can perform to be functioned effectively the above stated auxiliary magnetic pole portion 16.

20 Further, the present invention can apply to a generator and an electric motor, an inner rotor type

and an outer rotor type permanent magnet electric rotating machine, a rotary type and a linear type permanent magnet electric rotating machine, and a concentric winding stator structure and a distributed 5 winding stator structure permanent magnet electric rotating machine and same effects stated in the above can be obtained.

In this embodiment of the permanent magnet electric rotating machine according to the present 10 invention, a magnetic gap 14 is provided between the permanent magnet 9 and the auxiliary magnetic pole portion 16 which is adjacently provided at a peripheral direction to the permanent magnets 9.

Fig. 2 is an enlarged view showing a surrounding 15 portion of an optional permanent magnet 9 of the permanent magnet electric rotating machine shown in Fig. 1.

As shown in this figure, the permanent magnet insertion hole 10 is formed to provide the magnetic gap 20 14 at a peripheral direction end portion of the permanent magnet 9 and the permanent magnet 9 is inserted and fixed to the permanent magnet insertion hole 10. This magnetic gap 14 extends toward the axial direction and contacts to the permanent magnet 9 and 25 the auxiliary magnetic pole portion 16.

The functions of the magnetic gap 14 will be explained referring to Fig. 4A, Fig. 4B and Fig. 5A and

Fig. 5B.

5 Fig. 4A and Fig. 5A show a peripheral direction cross-sectional view of the surrounding portion of the permanent magnet 9 of the permanent magnet electric  
10 rotating machine, respectively. Fig. 4B and Fig. 5B show a relationship of a magnetic flux density distribution which is generated from a peripheral surface of the rotor 2 according to the rotor 9 of the permanent magnet electric rotating machine,  
15 respectively.

15 Fig. 4A side Fig. 4B show the rotor of the above stated embodiment of the permanent magnet electric rotating machine according to the present invention and Fig. 5A and Fig. 5B show a rotor of the permanent magnet electric rotating machine according to the prior art, respectively.

20 In the both rotors according to the present invention and the prior art, the magnetic pole piece portion 15 of the rotor iron core 8 functions as a member for transmitting the magnetic flux which is generated by the permanent magnets 9 to the stator 1. A member between the adjacent permanent magnet insertion holes 10, namely an auxiliary magnetic pole portion 16 in figures functions as an auxiliary magnetic pole for generating a reluctance torque.  
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Each of the graphs shown in Fig. 4B and Fig. 5B indicate the magnetic flux density distributions which

are generated the stator side surface (the outer peripheral surface of the rotor 2) of the rotor 2, respectively. In both figures, at the magnetic pole pieces 15, the magnetic flux which is generated from the permanent magnets 9 indicates substantially constant magnetic flux density distributions.

On the other hand, at the auxiliary magnetic pole portions 16, the magnetic flux from the permanent magnets 9 hardly transmit and the magnetic flux which is generated from the stator side surface (the outer peripheral surface of the rotor 2) of the rotor 2 become substantially zero.

However, in the conventional rotor of the permanent magnet electric rotating machine, as shown in Fig. 5A, since the permanent magnet 9 is arranged to embed a whole permanent magnet insertion hole 10, at a boundary portion between the magnetic pole piece portion 15 and the auxiliary magnetic pole portion 16, an abrupt change in the magnetic flux density distribution appears as shown in Fig. 5B.

In the permanent magnet electric rotating machine, in regardless of the existence of the electric power supply to the electric rotating machine, since the permanent magnet generates always the magnetic flux, the rotor receives always a force in response to a positional relationship between the stator salient pole portions 6 and the magnetic pole piece portions 15.

When the rotor rotates, since the position between the stator salient pole portion 6 and the magnetic pole piece portion 15 changes, a force for receiving the rotor 2 changes pulsatively and this change appears as the cogging torque and the torque pulsation. The more the change of the magnetic flux density distribution at the rotor peripheral direction is abruptly, the more the torque pulsation appears remarkably.

As the reasons stated in above, by providing the magnetic gap 14 as shown in this embodiment of the permanent magnet electric rotating machine according to the present invention, the change of the magnetic flux density distribution can be performed moderately.

A bridge portion 17 is formed between the auxiliary magnetic pole portion 16 of the surface of the rotor 2 and the magnetic pole piece portion 15 and also a distance is provided between the magnetic pole piece portion 15 and the auxiliary magnetic pole portion 16.

Accordingly, as shown the graph shown in Fig. 4B, the change of the magnetic flux density distribution according to the present invention appears moderately in comparison with the change of the magnetic flux density distribution shown in Fig. 5B according to the prior art, therefore in the present invention the cogging torque and the torque pulsation of the permanent magnet electric rotating machine can be

restrained.

Further, in the permanent magnet electric rotating machine in which the rotation direction is determined to only one direction, it may provide the magnetic gap 14 at one end of a peripheral direction of the permanent magnet 9.

Further, in the embodiment of the permanent magnet electric rotating machine according to the present invention, the rectangular shape permanent magnet 9 is used. However, it can employ the permanent magnet electric rotating machine having other shape permanent magnets, for example, an arc shape permanent magnet in which the magnetic gap 14 is formed and a trapezoid shape permanent magnet in which the magnetic gap 14 is formed.

In the permanent magnet electric rotating machine comprised of the other shape the similar effected obtained in this embodiment of the permanent magnet electric rotating machine according to the present invention can be obtained.

Other embodiments of the permanent magnet electric rotating machine according to the present invention will be explained referring to Fig. 6 to Fig. 8.

In the embodiment of the permanent magnet electric rotating machine shown in Fig. 6 and Fig. 7, a shape of the magnetic gap 14 is varied with the shape of the magnetic gap 14 of the above embodiment of the

permanent magnet electric rotating machine shown in Fig. 2.

5 In the embodiment of the permanent magnet electric rotating machine shown in Fig. 6, a dent portion is provided at a bottom portion of the permanent magnet insertion hole 10, and this dent portion the permanent magnet 9 is arranged and installed stable. As a result, a thickness at a rotation radial direction of the magnetic gap 14 is made thinner than a thickness at a 10 rotation radial direction of the permanent magnet 9.

15 As shown in figure, a face of an anti-stator side (an inner peripheral side of the rotor) of the magnetic gap 14 is formed to a stator side (an outer peripheral side of the rotor) in comparison with the face of the anti-stator side of the permanent magnet 9.

20 With the above stated structure of the permanent magnet electric rotating machine according to the present invention, the permanent magnet 9 can be positioned suitably to a predetermined position of the permanent magnet insertion hole 10.

25 Further, to determine the position of the permanent magnet 9, a non-magnetic material member is arranged or filled-up in the magnetic gap 14, even in this case the similar effects stated on the above embodiment can be obtained. For example, a solid body comprised of the non-magnetic material member is arranged in the magnetic gap 14, and using a vanish

member and an adhesion agent the solid body is fixed integrally to the permanent magnet 9, accordingly the permanent magnet 9 can be arranged stable.

Further, in the embodiment of the permanent magnet electric rotating machine according to the present invention shown in Fig. 7, a peripheral direction width of the magnetic gap 14 at the face of the stator side (the outer peripheral side of the rotor) is made larger than a peripheral direction width of the magnetic gap 14 at the face of the anti-stator side (the inner peripheral side of the rotor).

In Fig. 7, in particular a peripheral direction cross-section of the magnetic gap 14 is formed with a substantial triangular shape. With the above stated permanent magnet electric rotating machine structure according to the present invention, the magnetic flux passing-through the auxiliary magnetic pole portions 16 can circulate smoothly around the permanent magnets 9, therefore the permanent magnet electric rotating machine having the large reluctance torque can be obtained.

Further, in the embodiments of the permanent magnet electric rotating machines according to the present invention shown in Fig. 6 and Fig. 7, the face of the magnetic gap 14 at the stator side is formed substantially in parallel to the surface of the rotor 2 at the stator side.

With the above stated permanent magnet electric rotating machine structures according to the present invention, the magnetic saturation of the bridge portions 17 proceeds easily, according to the magnetic flux generated from the permanent magnets 9 through the magnetic pole piece portions 15 and the bridge portions 17, the magnetic flux for leaking to the auxiliary magnetic pole portions 16 can be restrained.

In the embodiment of the permanent magnet electric rotating machine according to the present invention shown in Fig. 8, to obtain the similar structure shown in the above stated embodiments, in reversal the shape of the rotor 2 is varied or modified. Namely, the bridge portion 17 having an inclined face 14b is constructed to extend substantially vertically against an inclined face 14a of the magnetic gap 14.

With the above stated structure permanent magnet electric rotating machine, since an inclination of the bridge portion 17 against the radial direction of the rotor 12 becomes large, a centrifugal force given on the magnetic pole piece portion 15 and the permanent magnet 9 can be supported according to a tensile force of the bridge portion 17.

In general, a durability property of the material of the permanent magnet electric rotating machine is higher at the tensile force than a sharing force. A durability property against the centrifugal force in

5 this embodiment becomes high in comparison with the above stated embodiment of the permanent magnet electric rotating machine in which the bridge portion 17 is positioned substantially right angle against to the radial direction of the rotor 2.

10 Accordingly, by forming thinner the bridge portion 17, it is possible to heighten an effective magnetic flux amount which is generated in the permanent magnet 9, and further it can rotate the rotor 2 at the high speed.

15 Furthermore embodiments of the permanent magnet electric rotating machines according to the present invention will be explained referring to Fig. 9 to Fig. 11.

20 In the embodiments of the permanent magnet electric rotating machines according to the present invention shown in Fig. 9 to Fig. 11, the magnetic gap 14 is provided between the magnetic pole piece portion 15 and the auxiliary magnetic pole portions 16, as shown in figures the magnetic gap 14 is formed at both ends of the magnetic pole piece portions 15.

25 The magnetic gap 14 extends toward the axial direction along to an edge portion of the stator side peripheral direction of the permanent magnet 9. By the provision of this magnetic gap 14, the bridge portion 17 as shown in figures is formed and the magnetic flux at the bridge portion 17 changes moderately, as a

result it is possible to restrain the cogging torque.

In those embodiments of the permanent magnet electric rotating machines according to the present invention, the magnetic gap 14 contacts to the 5 peripheral direction of face of the stator side of the permanent magnet 9, and further this magnetic gap 14 is formed to get into an inner portion side than a side of the peripheral direction end face of the permanent magnet 9.

10 Further, in the permanent magnet electric rotating machine structure according to the present invention shown in Fig. 10, the magnetic gap 14 is formed to extend toward an inner portion side of the permanent magnet 9 and in the permanent magnet electric rotating machine structure shown in Fig. 11, the magnetic gap 14 15 is formed to extend in a rectangular shape toward an inner portion side of the permanent magnet 9.

With the above stated permanent magnet electric rotating machine structures according to the present 20 invention, the magnetic flux for leaking to the auxiliary magnetic pole portion 16 can be decreased, the magnetic density at the magnetic pole piece portion 15 is heightened, accordingly the efficiency as the permanent magnet electric rotating machine can be 25 heightened.

Furthermore embodiments of the permanent magnet electric rotating machines according to the present

invention will be explained referring to Fig. 12 to Fig. 14.

In a case where the rotor comprised of the permanent magnet embedding type structure permanent magnet electric rotating machine rotates at the high speed, the centrifugal force received on the permanent magnet 9 increases and also the burden of a member for supporting the permanent magnet 9, namely the burdens of the magnetic pole piece portion 15 and the bridge portion 17 increases.

In a case where in response to the above burden the thick supporting member of the permanent magnet electric rotating machine is provided, the distance between the surface of the rotor 2 and the permanent magnet 9 becomes large and the magnetic flux leaks to the auxiliary magnetic pole portion 16. As a result, there causes problems that the magnetic flux for transmitting from the permanent magnet 9 to the stator 1 decreases and also the torque decreases.

From the above stated reasons, at the peripheral direction both ends of the permanent magnet 9 at the face of the stator side, as shown in a cross-section shown in Fig. 12, the magnetic gap 14 is formed to extend to the axial direction. Further, to sandwich or to form the magnetic gap 14 a magnetic pole piece supporting member 18 is inserted at the axial direction and fixed to the magnetic pole piece portion 15 and the

auxiliary magnetic pole portion 16.

Fig. 13 shows one example of the magnetic pole piece supporting member 18. The magnetic pole piece supporting member 18 is comprised of a member of a non-magnetic resin material member having J shape and has an inner hollow portion. A lateral direction width of the inner hollow portion of the magnetic pole piece supporting member 18 corresponds to a lateral direction width of the magnetic gap 14.

Fig. 14 is an axial direction cross-sectional view showing the permanent magnet electric rotating machine having the rotor 2 in which the magnetic pole piece supporting member 18 is inserted from both sides of the magnetic pole piece portion 15 and the auxiliary magnetic pole portion 16.

Herein, the magnetic gap 14 restrains the magnetic flux which leaks from the magnetic pole piece portion 15 to the auxiliary magnetic pole portion 16. The magnetic pole piece supporting member 18 works as a role of a medium body for supporting a centrifugal force of the permanent magnet 9 given on the magnetic pole piece portion 15 and a centrifugal force of the magnetic pole piece portion 15 itself according to the auxiliary magnetic pole portion 16. As a result, the supporting force of the permanent magnet 9 against the centrifugal force can be heightened.

Further, after the assembling of the rotor 2, by cutting the bridge portion 17 shown in Fig. 12 and further by maintaining the supporting force of the magnetic pole piece portion 15 according to the 5 magnetic pole piece supporting member 18, the leakage magnetic flux according to the bridge portion 17 can be decreased.

10 A further embodiment of the permanent magnet electric rotating machine according to the present invention will be explained referring to Fig. 15.

15 In this embodiment of the permanent magnet electric rotating machine, as shown in figure the magnetic gap 14 is provided between the magnetic pole piece portion 15 and the auxiliary magnetic pole portion 16. A permanent magnet supporting member 19 is provided between the permanent magnets 9. The magnetic pole piece portion 16 and this permanent magnet supporting member 19 are formed by assembling a magnetic material member 19a and a non-magnetic 20 material member 19b.

25 The permanent magnet supporting member 19, as shown in figure, is comprised of an assembling member of the magnetic material member 19a and the non-magnetic material member 19b. The magnetic material member 19a and the non-magnetic material member 19b are joined according to a manner of welding process etc..

The magnetic material member 19a is constituted by the magnetic material member to transmit the generation magnetic flux of the permanent magnet 9 to the magnetic pole piece portion 15. On the other hand, the non-magnetic material member 19b is constituted by the non-magnetic material member to restrain the leakage magnetic flux from the permanent magnet 9 to the auxiliary magnetic pole portion 16.

With the above stated permanent magnet electric rotating machine structure according to the present invention, since the centrifugal force given to the permanent magnet 9 is supported by the auxiliary magnetic pole portion 16 through the permanent magnet supporting member 19, only the centrifugal force of the magnetic pole piece portion 15 is given to the bridge portion 17. Accordingly, a length of the bridge portion 17 at the radial direction can be shortened and further the magnetic flux leakage from the permanent magnet 9 can be lessened.

Besides, in the embodiments of the permanent magnet electric rotating machine structures shown in Fig. 9 to Fig. 11, it is effective to arrange or fill up a non-magnetic material member.

The thickness of the magnetic pole piece portion 15 is set to a thickness necessary to obtain the sufficient magnetic flux. The magnetic gap 14 is punched out at the stator side of the permanent magnet

9 with the shapes as shown in Fig. 9 to Fig. 11 and in this magnetic gap 14 a non-magnetic material member, for example such as an adhesive agent and a vanish member, is filled up.

5       With the above stated permanent magnet electric rotating machine structure according to the present invention, without the thick thickness of the magnetic pole piece portion 15 at the radial direction, the centrifugal force received by the permanent magnets 9  
10      and the magnetic pole piece portions 15 can be supported by the magnetic gap 14.

15      Further, as the material for the permanent magnet 9, it is possible to employ a resin mold type magnet. In this case, in replace of the non-magnetic material member for filling up the magnetic gap 14, it can insert the resin mold type magnet with a shape of by suiting the shape of the permanent magnet insertion hole 10 and the shape of the magnetic gap 14.

20      In other words, to a plastic magnet itself it is possible to serve the above stated role by the magnetic gap 14. Further, as shown in Fig. 16, it is effective to provide larger the peripheral direction width ( $\theta a$ ) of the auxiliary magnetic pole portion 16 than the peripheral direction width ( $\theta m$ ) of the permanent magnet 9.  
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With the above stated permanent magnet electric rotating machine structure according to the present

invention, the weight of the permanent magnet 9 for producing the centrifugal force given on the bridge portion 17 is lessened and the thickness of the bridge portion 17 can make thin, accordingly the leakage 5 magnetic flux for leaking from the magnetic pole piece portion 15 to the auxiliary magnetic pole portion 16 can be decreased.

Further, since the peripheral direction width of the permanent magnet 9 can be formed thin, the magnetic flux generated by the permanent magnet 9 decreases. 10 However, the reluctance torque according to the auxiliary magnetic pole portion 16 increases relatively. This fact is effective to use a high cost neodymium magnet as the permanent magnet 9.

15 By compensating a part of the cost down by decreasing an amount of the permanent magnet 9 according to the reluctance torque of the auxiliary magnetic pole portion 16, an improvement of a cost performance of the permanent magnet electric rotating 20 machine can be attained.

Further, by applying the permanent magnet electric rotating machine stated in above to the electromotive vehicle in particular to an electric vehicle, since the cogging torque can be small, it can mount a stable 25 permanent magnet electric rotating machine drive apparatus which can start smoothly. As a result, the electric vehicle having the long running distance per

one time charging or having the small consumption electric power can be provided.

According to the present invention, the permanent magnet electric rotating machine having the small torque pulsation can be constituted. Further, according to the present invention, it is possible to set the positioning of the permanent magnet of the permanent magnet electric rotating machine.

According to the present invention, in the permanent magnet electric rotating machine it is possible to circulate smoothly the magnetic flux passing-through the auxiliary magnetic pole portion around the permanent magnet. Further, in the permanent magnet electric rotating machine it is possible to restrain the magnetic flux for leaking from the member of the stator side of the magnetic gap in the permanent magnet to the auxiliary magnetic pole portion.

According to the present invention, the permanent magnet electric rotating machine having the small torque pulsation can be realized. Further, according to the present invention, it is possible to restrain the magnetic flux for leaking from the permanent magnet at the face of the stator side to the auxiliary magnetic pole portion of the permanent magnet electric rotating machine.

According to the present invention, it is possible to secure the supporting force against the centrifugal

force given on the permanent magnet of the permanent magnet electric rotating machine. Further, according to the present invention, the electromotive vehicle, which is comprised of the permanent magnet electric rotating machine, having the small cogging torque and having the stable drive apparatus can be provided.